REMOTE SENSING CENTRE

# MOOSE HABITAT ANALYSIS IN NORTH-CENTRAL MANITOBA FROM LANDSAT DATA

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## ABSTRACT

The landscape and associated renewable resources in approximately 152,000 $km^2$ of north central Manitoba have been affected by the alteration of water regimes through hydroelectric projects.

Treaty Indian Bands claim the local moose (Alces alces) population has declined because of habitat deterioration resulting from the hydro projects. The Bands depend upon moose for sustenance. They have requested a moose population survey for the entire area in order to determine the present status of the resource. Baseline habitat data that are required to stratify the area for an efficient aerial survey were not available.

The purpose of this study was to assess the operational applicability of generating the required habitat maps and associated area tabulations utilizing the technology of remote sensing. An interactive digital image analysis system, called the Applied Resources Image Exploitation System (ARIES)-II (Dipix Ltd.) was used to process Landsat multispectral data. An unsupervised clustering algorithm was used to classify four Digital Image Correction System (DICS) scenes from July 5, 1979.

The results of the classification were compared to ground reference data which included Forest Inventory information and panchromatic aerial photography.

Hard-copy output information was in the form of colour-coded thematic maps. The overall accuracy for the cover classes on the thematic maps was eighty-four percent. Mapping success for individual cover classes varied from forty seven percent (mixed wood) to ninety-three percent (water).

The map format and accuracy levels were reviewed by staff of the Manitoba Wildlife Branch. The decision was to proceed with the aerial census based on the Landsat data as it appeared to adequately meet their requirements.

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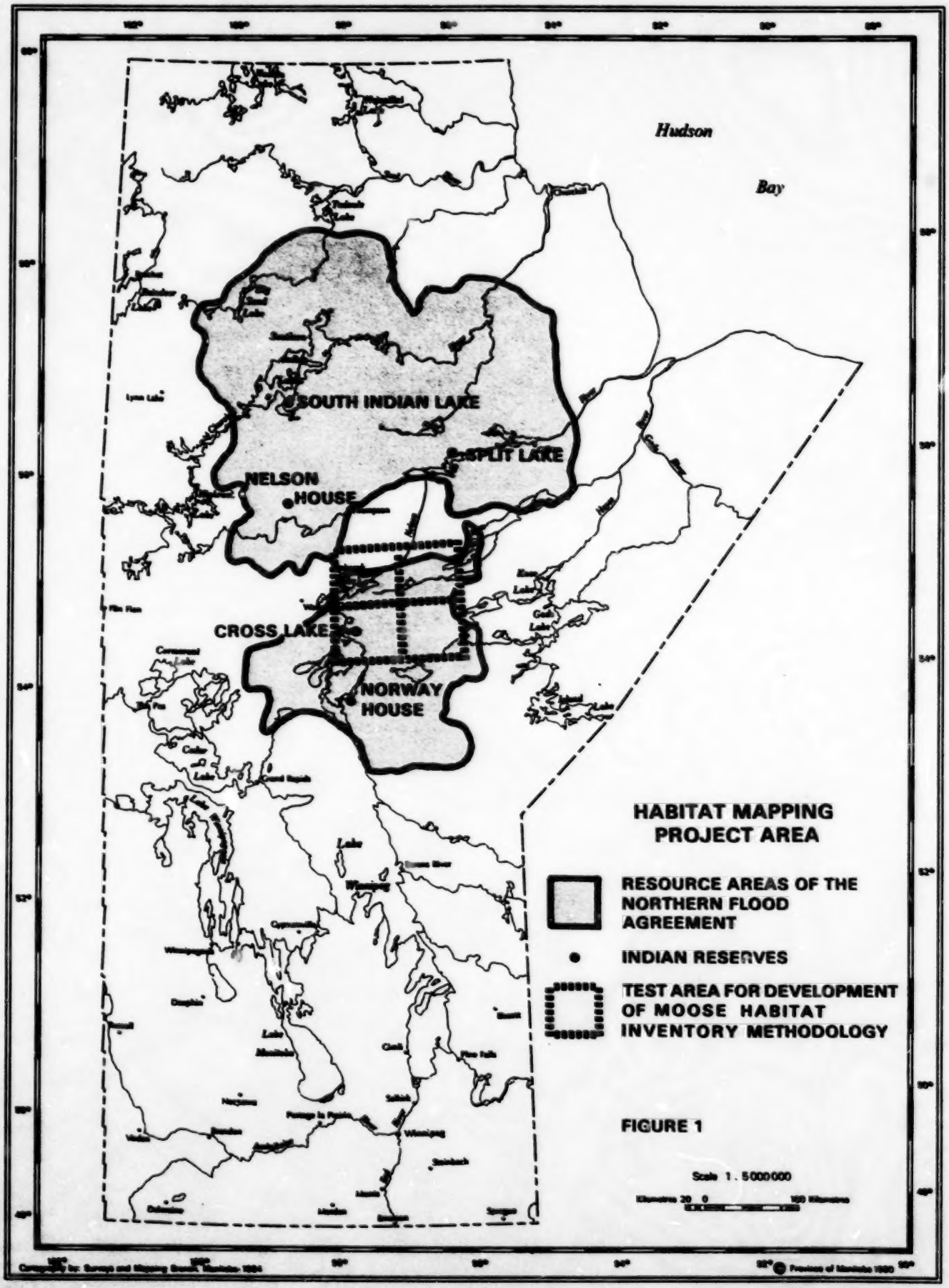
## 1. BACKGROUND

The Manitoba Hydro Electric Board is engaged in the development of hydro-electric power projects such as the Churchill River Diversion. Alterations to the associated river basin water regimes are affecting the resource base (wildlife and fisheries) relied upon by the residents of the neighboring Indian Reserves (Figure 1). Manitoba Hydro and the Province of Manitoba are attempting to mitigate these activities through the Northern Flood Agreement. A Wildlife Advisory and Planning Board, composed of local Treaty residents, was established as part of the Agreement to consult with the Manitoba Government and Manitoba Hydro on wildlife-related matters.

On September 14, 1982, a resolution was submitted to the Manitoba Department of Natural Resources by the Board directing that a moose population survey be conducted immediately within the 152,000 $km^2$ Northern Flood Agreement Resource Area. The Manitoba Government was obligated to conduct the survey.


Hudson
Bay
SOUTH INDIAN LAKE
SPLIT LAKE
NELSON HOUSE
CROSS LAKE
NORWAY HOUSE
HABITAT MAPPING PROJECT AREA
RESOURCE AREAS OF THE NORTHERN FLOOD AGREEMENT
INDIAN RESERVES
TEST AREA FOR DEVELOPMENT OF MOOSE HABITAT INVENTORY METHODOLOGY
FIGURE 1
Scale 1 : 5000000

Stratified sampling, with stratification based upon known habitat distribution within the study area was chosen as the sampling design. This method required that maps be made which provided the area and distribution of different types of habitat within the study area.

Suitable habitat base data were not available for the Northern Flood Agreement Area. Information from the Manitoba Forest Inventory Program was evaluated as a possible alternative but it was found to be not suitable for a number of reasons. The information was only available for approximately 60% of the Northern Flood Area. Area calculations were gathered by townships (36 square mile units) but not collected into any larger groupings, thus making the data too site specific. Finally, not all the cover types used by the Program are applicable as moose habitat cover types (see discussion).

Two alternatives were available to the Wildlife Branch: conduct 400-metre aerial transect surveys over the entire 152,000 $km^2$ area or conduct a habitat inventory for preliminary stratification purposes and then sample from habitats in proportion to the variance of within - habitat moose densities.

The Wildlife Branch estimated that if the entire Northern Flood area was flown, the cost would be several hundred thousand dollars. The only feasible alternative was to conduct a preliminary habitat inventory. However, there were two major limitations to such an inventory: it had to be done expediently and at reasonable cost. Information was required within eleven months in order to begin the aerial surveys.

At the time that these deliberations were taking place, Manitoba had just received a DIPIX-ARIES II digital image analysis system. The system was on loan to the Manitoba Remote Sensing Centre from the Canada Centre for Remote Sensing as part of a Technology Enhancement Program (TEP). Recent successful moose habitat studies based on computer analysis of Landsat digital multispectral data by LaPerriere et al. (1982) led the Wildlife Branch to initiate a pilot moose habitat inventory to investigate the technology's applicability to the habitat inventory at hand.

## 1.1 The Study

The objective of this study was to evaluate computer-analysed Landsat digital information as a habitat inventory tool and, if successful, develop a methodology for conducting the moose habitat inventory for the Northern Flood Agreement Resource Area. The study was conducted jointly by staff of the Manitoba Remote Sensing Centre and the Wildlife Branch as a Technology Enhancement Program (TEP) demonstration project.

The study was guided by the following criteria:

1) The methodology had to be conducive to a large-scale inventory such as the Northern Flood Agreement Resource Area.

2) Funding for the inventory was limited--no greater than $30,000. The Department of Northern Affairs, Manitoba had committed these funds for the 1982/83 and 1983/84 fiscal years only. Limited additional funds and staffing were to be provided by the Wildlife Branch, Manitoba Department of Natural Resources.

3) The southern block of the Northern Flood Agreement area, Figure 1, had to be completed by December 1, 1983 with balance of the area completed by December 1, 1984.

4) Habitat information was to be gathered by the following cover classes:

   a) deciduous

   b) mixed deciduous/conifer

   c) conifer

   d) bog (includes fen, muskeg)

   e) marsh

   f) open water

5) A minimum level of mapping accuracy could not be established prior to project initiation since it was not possible to forecast what degree of population estimate error would arise from the various degrees of error within the individual cover types. Contingency tables of the cover type classification would be assessed to determine the biological implications of errors.

6) Colour-coded habitat maps were required at a scale of 1:150,000.

7) Area tabulations had to be summarized for each cover class by 10 $km^2$ area units and by entire mapsheet.

## 2. THE TEST AREA

### 2.1 Location

In order to assess automated image analysis technology and develop a habitat inventory methodology for the entire Resource Area, a test area was chosen in the Cross Lake region (Figure 1). It was located between 54°30' N and 55°30' N latitude and 96°00' W and 98°00' W longitude and incorporated the north half of National Topographic Series (NTS) map sheet 63I and the south half of NTS map sheet 63P.

The area was chosen for two reasons: it encompassed much of the region where there was greatest concern over moose populations and it was representative of much of the diversity in habitat conditions found elsewhere within the Northern Flood Area.

### 2.2 Physiographic features

The major portion of the area is underlain by lacustrine clays and a sand belt surrounding the Upper Nelson River area and is classified B21, Nelson River (Rowe, 1959). It is bordered by Precambrian rock formations on the north and east and by Palaeozoic lowlands to the west and south. Characteristic soils include Podzols on the drier, better-drained slopes, and organics (peat) in the bog areas. A discontinuous occurrence of permafrost is also found on better-drained, gently-sloped bog sites. These sites occur as

complexes of peat plateaus and patterned and/or horizontal fens. Collapse scars on the edges and centre of the peat plateaus become more extensive toward the south end of the test area.

## 2.3 Vegetation

The vegetation in the area is dominated by evergreen coniferous forests. Black spruce (*Picea mariana*) is the most common species found on a range of sites. Stands of jack pine (*Pinus banksiana*) are prevalent on the higher, better-drained sites. Stands of white spruce (*Picea glauca*) and balsam fir (*Abies balsamea*) occur along riverbanks, islands and low ridges. Scattered stands of trembling aspen (*Populus tremuloides*) and white birch (*Betula papyrifera*) are also found on those sites. Tamarack (*Larix laricina*), willow (*Salix spp.*), and alder (*Alnus spp.*) are commonly found in low areas. Extensive and repeated wildfires have disturbed most of the forest cover at one time or another. Many areas are, therefore, in the process of regeneration.

## 3. METHODS

### 3.1 Data Acquisition

LANDSAT mircofiche files at the Manitoba Remote Sensing Centre were used to identify the most appropriate multispectral scanner (MSS) data for the study (Table 1). The criteria for selection was: the most recent cloud-free images that coincided with the period of maximum phenological activity (early July to early August) for vegetation in the area.

The product format chosen was Digital Image Correction System (DICS) images. This geo-corrected format was chosen because it was imperative that there be easy geographical correlation with the National Topographic Series (NTS) map sheets and the ground reference data. It was considered that there was too little time available to geometrically correct computer-compatible Landsat tapes in-house.

Table 1. The four DICS images chosen for the study were:

| Frame Number | Date of Images | DICS Map Sheet Number | NTS Map Sheet Number |
|---|---|---|---|
| 21625-16451 | 5 July 1979 | 063I13 | 63I-NW |
| 21625-16451 | 5 July 1979 | 063I15 | 63I-NE |
| 21625-16451 | 5 July 1979 | 063P05 | 63P-SW |
| 21625-16451 | 5 July 1979 | 063P07 | 63P-SE |

### 3.2 Reference Data

Manitoba Forest Inventory township maps (scale 1:63,360) served as the basis for comparison between Landsat thematic data and ground cover. These maps were the most current (1968-1972) and detailed information available for the test area. Forested and non-forested cover are grouped into stands of common vegetation and site characteristics. Tabular area summary sheets accompany the township maps. Each stand is referenced by number.

Aerial photographs were also utilized to determine initial results of the classifications on the colour monitor. They were 1976 panchromatic photographs at a scale of approximately 1:56,000.

Forest fires and dates of occurrence (1960-1982) were plotted on a 1:500,000 base map. That information was acquired from the Foresty Branch, Department of Natural Resources.

### 3.3 LANDSAT Data Classification

Digital image analyses using the DIPIX - Applied Resources Image Exploitation System (ARIES) - II were conducted at the Manitoba Remote Sensing Centre between January 1st and June 1st, 1983.

An unsupervised clustering analysis algorithm employing a maximum likelihood classifier (Letts, 1978) was utilized for classification purposes. This classification technique was used primarily because it required little field information and the cover classes to be mapped were expected to be spectrally separable. The procedure was as follows: A histogram of the pixel frequencies was constructed from the multi-dimensional Landsat data. The histogram

was then searched for peaks which are referred to as 'local maxima'. Up to 32 local maxima positions are stored in order of significance. Each maximum was identified by its mean and standard deviation in each dimension. The maxima are then merged into clusters on the basis of their statistical similarities. The clusters represent hypothetical training areas which are used to generate signature files by means of a parallel-piped classifier. A standard maximum likelihood classification was then performed using these signature files.

The classified results were displayed on the colour TV monitor to determine the results of the classification. Spectral classes were correlated with ground cover by using the panchromatic aerial photography (scale 1:56,000).

When the results of the classified image were considered satisfactory, isolated pixels ($\leq 5$) were assigned to the surrounding class. A computer tape of the classification was then sent to the Canada Centre for Remote Sensing where a colour-coded thematic map was produced using an Applicon colour plotting system.

### 3.4 Classification Accuracy

Four thematic maps, representing the four DICS scenes, were produced. Four townships (373 $km^2$), or approximately 10% of each mapsheet, were randomly selected for accuracy assessment.

The classified townships were compared to Forest Inventory data as defined in the Forest Inventory "Field Instructions Manual".

Within the selected townships a sampling unit of a legal subdivision (16.18 ha) was used as the basis of comparison. A 16.18 ha grid was overlayed on the corresponding townships of both the thematic and Forest Inventory maps.

A contingency table was then constructed to demonstrate the similarities and differences between Forest inventory and the LANDSAT thematic data. Tables were compiled for each mapsheet and then merged into a composite (Table 2).

The composite table was analysed in the following ways:

a) the proportion of the sampling units in which the Forest Inventory vegetation types were uniquely represented by a theme created by the digital classification, and

b) the proportion of the sampling units in which each theme derived from the digital analysis consisted solely of one Forest Inventory vegetation type.

Confidence intervals were calculated for each proportion (Snedecor and Cochrane 1968: 210-211) (Tables 3 and 4).

Comparisons were complicated by the nature of the data recorded on Forest inventory maps. This data were gathered to evaluate the amount of merchantable timber. To this end there is site-specific information on merchantable softwood/hardwood stands. Non-merchantable areas have been assessed in a more general manner. For example, there are large areas mapped as treed muskeg (700). These areas can have a range of tree canopy density classes from 10 percent to greater than 60 percent of the area but will not produce merchantable trees within a

certain time period. There is no indication of this variability on the Inventory maps. Those "700" areas were classified on the thematic maps as either conifer or bog. A second problem arose from the Forest Inventory maps for burned and disturbed sites. If an area was in an early stage of succession no attempt was made to identify ground cover vegetation. Instead the site was coded as to the merchantable tree species most likely to evolve on the site.

## 4. RESULTS

Four colour-coded Landsat thematic maps were produced for the study area, at a scale of 1:150,000. A total of 8692 sampling units illustrated how the thematic maps compared to Forest Inventory information (Table 2). The overall accuracy of the digital classification was 84 percent.

Tabulations from the four thematic map sheets are presented in Tables 2, 3 and 4.

Table 2. A contingency table of sample units from the Landsat thematic maps to the Forest Inventory information.

| Landsat Theme | Forest Inventory Categories | | | | | | |
|---|---|---|---|---|---|---|---|
| | Conifer | Bog | Marsh | Mixed Wood | Deciduous | Water | Total Units |
| Dark Green | 2491 | 669 | 4 | 59 | 6 | 3 | 3244 |
| Orange | 118 | 2756 | 24 | 41 | 2 | 6 | 2947 |
| Yellow | 0 | 11 | 68 | 0 | 0 | 34 | 113 |
| Light Green | 99 | 130 | 10 | 225 | 19 | 0 | 483 |
| Red | 9 | 8 | 2 | 17 | 132 | 0 | 168 |
| Dark Blue | 12 | 76 | 22 | 1 | 1 | 1625 | 1737 |
| TOTAL | 2729 | 3650 | 130 | 343 | 160 | 1688 | 8692 |

Table 3. A table depicting the probability that a vegetation type will be uniquely represented by one colour on a thematic map.

| Vegetation Type | Number of Sampling Units | Percentage Correct | 95% Confidence Interval for Proportion |
|---|---|---|---|
| Conifer | 2729 | 0.913 | 0.902 - 0.923 |
| Bog | 3650 | 0.755 | 0.741 - 0.769 |
| Marsh | 130 | 0.523 | 0.437 - 0.609 |
| Mixed wood | 343 | 0.656 | 0.606 - 0.706 |
| Deciduous | 160 | 0.825 | 0.766 - 0.884 |
| Water | 1668 | 0.974 | 0.967 - 0.982 |
| OVERALL | 8680* | 0.841 | 0.833 - 0.848 |

* The number of samples in Table 3 and Table 4 is not identical because of some unclassified pixels.

Table 4. A table depicting the probability that a colour on a thematic map will uniquely represent a vegetation type.

| Colour Interval | Number of Sampling Units | Proportion Correct | 95% Confidence Interval for Proportion |
|---|---|---|---|
| Dark Green (Conifer) | 3244 | 0.768 | 0.753 - 0.782 |
| Orange (Bog) | 2947 | 0.935 | 0.926 - 0.944 |
| Yellow (Marsh) | 112 | 0.602 | 0.512 - 0.692 |
| Light Green (Mixed wood) | 483 | 0.466 | 0.421 - 0.510 |
| Red (Deciduous) | 168 | 0.786 | 0.724 - 0.848 |
| Blue (Water) | 1737 | 0.936 | 0.924 - 0.947 |
| OVERALL | 8692 | 0.840 | 0.832 - 0.847 |

## 5. DISCUSSION

The proportion-correct columns of Tables 3 and 4 indicate the success of isolating the various cover classes. The cover classes that contained homogeneous environments such as conifer, deciduous and water had the higher degrees of proportion correct. The cover types that had poorer classification results were the transitional cover classes such as marsh, bog and mixedwood. These classes contained a variety of characteristics which could lead to confusion with other similar cover types. For example, in this study, marsh was considered a transitional class between water and bog. The criteria used to classify this cover type varied from the manual visual photogrammetric methods of the Forest Inventory Program to the automated unsupervised clustering algorithm. The maximum and minimum limits for decision making in these processes cannot be adjusted to coincide with each other. The result is what is considered to be correctly classified as marsh by one method may be termed incorrect by the other method.

The following discussions by individual cover type will attempt to rationalize the inconsistencies identified in Tables 2 and 3.

### Conifer Category

Of the 3244 conifer sites sampled on the thematic maps, Forest Inventory data indicates that only 2491 were conifer, which resulted in a general accuracy level of 76.8%. Of the 753 errors, 669

(89%) occurred where the site was classified muskeg/bog ("700") by Forest Inventory. The characteristics of this category were discussed earlier in this paper. Many of the small "islands" of conifer in the muskeg were classified by the computer as conifer, but due to their low merchantable value were grouped into the 700 category by Forest Inventory. This fact was confirmed by subsequent checks of these sites on aerial photography and flights over the test area.

This type of error is inherent to any study when two formats of map with different criteria for classification are compared.

Bog Category

A total of 2947 bog/muskeg sites were evaluated on the thematic maps with 191 errors (6.5%) being recorded. Of the 191 errors, 118 occurred when bog was identified as conifer on the thematic maps. Again the same rationale as discussed in the previous category can be applied here. Many of the apparent errors occurred where the bog sites had a high degree of tree cover (>30% density), enough to be classified as conifer on the thematic maps, but not of sufficient size, quality and/or volume to be classified by Forest Inventory as productive forest land.

The variation in mapping criteria between the two methods was again a major factor in these identified discrepencies.

Marsh Category

The number of sites assessed for the marsh category is much lower than previous categories. However enough were sampled to give an indication of the relative success of classification (Tables 3 and 4). All errors arose where marsh was confused with bog and water.

The most logical explanation for the confusion--differences in mapping criteria--has been discussed earlier in this section. However, there is a major factor that further contributes to error in the classification along the river course of the Nelson River. The problem is the seasonal fluctuation in water levels due to Manitoba Hydro's manipulation of water levels in the Nelson River Basin. Water levels vary substantially between the date of the photography used for Forest Inventory map production and the date of the procurement of Landsat imagery used for this study. Water levels were lower when the Landsat scene was imaged than when the Forest Inventory photography was obtained. Many areas that were open water in the photography were in fact shallow and similar to marsh conditions when the Landsat scene was recorded.

Mixed Wood Category

The mixed wood category had the lowest level of accuracy of all six categories (46.6%). These results are not surprising considering this is a transition category.

One-half of all errors occurred where Landsat identified mixed wood as conifer or deciduous. Since the decision making process using the unsupervised algorithm is done by computer it is not possible to use the same parameters for classifying mixed wood as were used during the Forest Inventory mapping. Therefore the resulting classification cannot be expected to coincide.

A portion of the error is also attributable to inaccuracies in the Forest Inventory data. Aerial inspection of four of these

apparent error sites indicated Forest Inventory had incorrectly mapped three of them. Thematic maps had correctly classified the stands as conifer because there was less than 10% hardwood in the stand.

In light of the confirmed errors in the Forest Inventory mapping it is felt that the overall accuracy of the mixed wood site class on the thematic maps may be much higher than what is indicated in the tables.

Deciduous Category

A total of 168 sites were assessed with 36 errors found (78.6% accuracy). Of the errors, 47% occurred where deciduous was classified as mixed wood. Approximately 20% of the errors were deciduous being classified as bog/muskeg. These may not be error as willow/alder can be grouped with bog/muskeg by Forest Inventory. The reflectance values from these sites would logically be similar to deciduous.

Water Category

A total of 1737 sites were sampled with 112 errors detected. Of the errors, 76 were water classified as bog and 22 were water classified as marsh. These two cover types account for 87.5% of the errors. Confusion of these cover types is logical since water absorbs light so efficiently that even areas that have partial vegetative cover (wet marsh) can be masked by the water lying below. Also, as mentioned earlier water levels can fluctuate greatly in the area resulting in temporary high water levels in areas that are normally bog or marsh.

Significance of Identified Errors to an Aerial Moose Survey

Tables 3 and 4 identify the degree of accuracy by which various cover types were mapped during the study. However these accuracy indicators cannot by themselves, tell the biologist whether the classification can supply an acceptable mapping product.

The biologist must study each of the sources of error within each cover type and subjectively decide what significance the confusion error will have upon the subsequent population survey. This statement is based upon the assumption that not all cover classes are of the same value as habitat. In Manitoba, as elsewhere, the deciduous and mixed wood stands are considered to be the most important cover types for winter aerial moose surveys. Since the surveys are flown during periods of stable weather conditions the moose are expected to be concentrated in these feeding areas. Errors in the estimation of the quantity of these higher-quality habitat types would have a greater potential effect on the overall population estimate because of higher densities on these areas.

Table 5 indicates errors which are considered to be most significant prior to aerial surveys. Since the deciduous and mixed wood stands are both considered top priority for the surveys, they are treated as such on the table. Where the higher quality habitat types are mapped as poorer habitat types there is expected to be an underestimate in population numbers. The converse is also true.

Table 5. A contingency table (Table 2) with the most significant sources of error identified.

(///) underestimate ( ) overestimate

| Landsat Theme | Forest Inventory Categories | | | | | | |
|---|---|---|---|---|---|---|---|
| | Conifer | Bog | Marsh | Mixed Wood | Deciduous | Water | Total Units |
| Dark Green | 2491 | 669 | 4 | (59) | (6) | 3 | 3244 |
| Orange | 118 | 2756 | 24 | (41) | (2) | 6 | 2947 |
| Yellow | 0 | 11 | 68 | 0 | 0 | 34 | 113 |
| Light Green | (/99 | ///130 | ///10 | ////225) | 19 | 0 | 483 |
| Red | (//9 | ////8 | ///2 | ////17) | 132 | 0 | 168 |
| Dark Blue | 12 | 76 | 22 | (1) | (1) | 1625 | 1737 |
| TOTAL | 2729 | 3650 | 130 | 343 | 160 | 1688 | 8692 |

The final decision to proceed with an operational mapping program using the automated image analysis technology is based on some measure of subjectivity. The real significance of the errors and the quality of the information cannot be judged until the aerial surveys are completed, and estimates of density, are calculated for each cover type.

## 6. CONCLUSIONS

The objective of this project was to assess the practicality of using automated analysis of LANDSAT digital data to conduct an operational moose habitat inventory in northcentral Manitoba.

The authors acknowledge that classification techniques other than those used might increase accuracy levels. However it was believed that the unsupervised clustering algorithm could provide an optimum speed of classification with a minimum amount of necessary field data.

In July, 1983 the thematic maps and assessment of the project were presented to the biologists of the Department of Natural Resources who will be involved in the upcoming aerial moose census. The concensus was that the map format and accuracy levels would be adequate for their needs. The recommendation was to proceed with an operational program.

During the winter of 1983-84 aerial census flights will be conducted in the entire southern block of the Northern Flood Agreement area. Statistically representative areas (blocks) will be flown for all cover types. All moose will be counted in each block. In addition, general notes will be made on the actual vegetation cover within each block. Estimated densities and confidence intervals will be calculated for each cover type and an overall population estimate will be formulated. Cover maps prepared during the flights will be compared to the thematic maps as a further accuracy assessment.

The pilot study has indicated that automated digital image analysis of Landsat data appears to have direct application to mapping wildlife habitat on a regional basis. The technology is particularly valuable in remote areas where little ground reference material is available.

A final assessment of the technology will be made in late 1984 once the initial aerial surveys have been evaluated.

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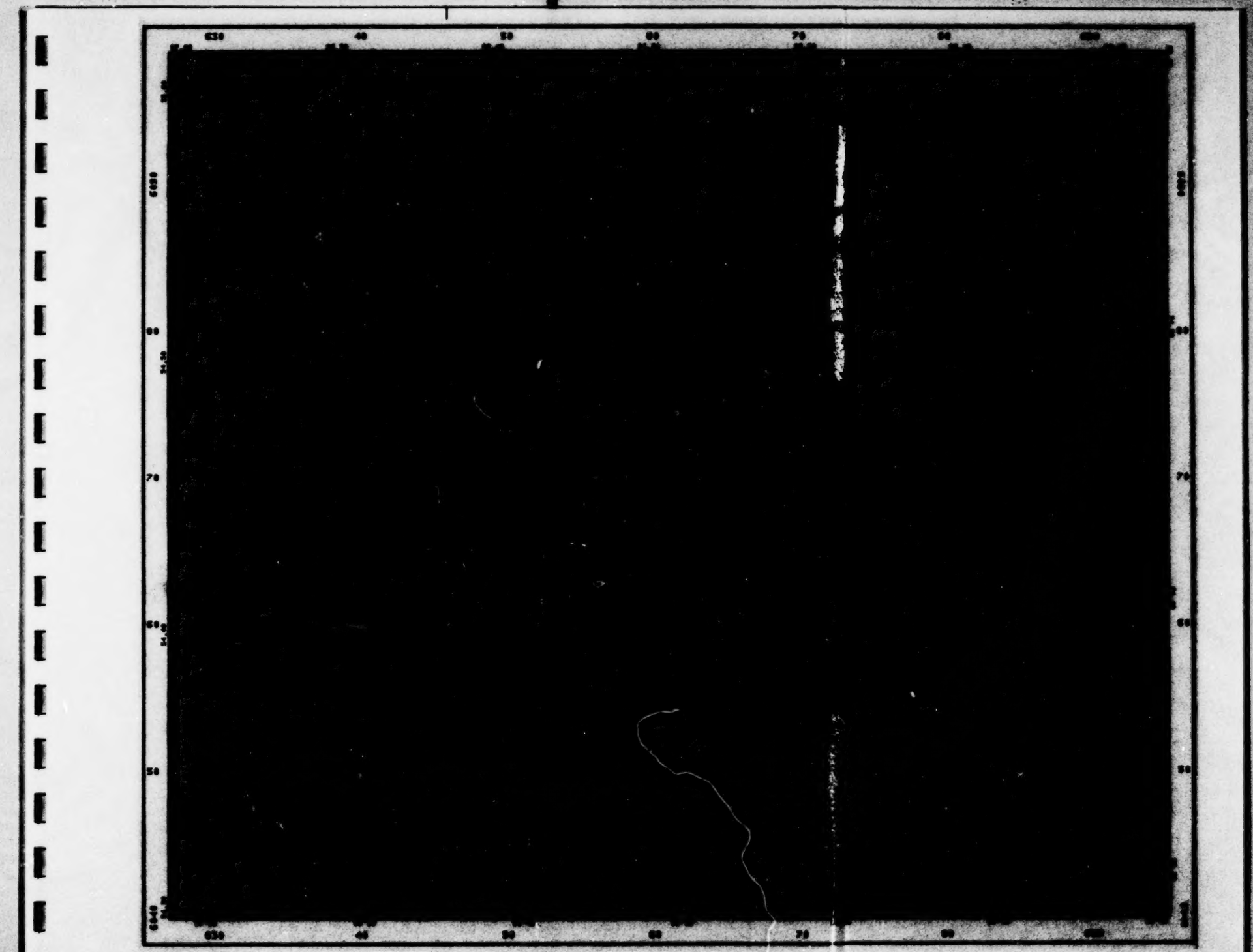
# APPENDIX



# CROSS LAKE 63I NE

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POOR

QUALITY

ORIGINAL